Peat as a feed supplement for animals: a review

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ABSTRACT: Peat is an easily available natural material and a source of biologically active substances widely used, not only in agriculture but in human and animal medicine as well. In recent years, interest in the use of peat as a feed supplement has increased, particularly due to its capability to prevent enteric diseases and to stimulate growth in piglets and pigs. The purpose of this review was to compare the advantages and risks associated with the use of peat for animal nutrition based on the literature available. Beneficial effects of various peat preparations on digestion, growth and the immune systems of animals as well as the absorbent and detoxifying capabilities are associated with the high content of favourable humic substances. One disadvantage of using peat preparations is the considerable diversity of the various types of peat caused by different biological, chemical and geological conditions during formation. Biological activity of various peat preparations is associated not only with fluctuations in the chemical compositions, but also with different application techniques. Based on the existing studies, it is unclear which application technique is most effective for respective animal species. Further studies should be conducted to elucidate the problem, with the inclusion of farm animals. One potential risk of peat feeding is the possibility of primary or secondary mycobacterial contamination. As long as feed rations are supplemented with peat preparations, it is essential to minimise the potential contamination risk during mining, processing and storage.

Keywords: humate; humic substances; humic acid; fulvic acid; moor; mycobacteria; tuberculosis; *Mycobacterium avium* complex

Contents

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1. Introduction

Peat is an easily available natural material and a source of biologically active substances widely used, not only in agriculture but also in human and animal medicine. Various peat extracts have been successfully applied to a variety of clinical applications. Peat is viewed as a traditional preventive and therapeutic agent against gastric and digestive problems such as hyperacidity, diarrhoea, gastric ulcers, dysentery etc. (Kuhnert et al., 1989, 1991; Roost et al., 1990; Banaszkiewicz and Drobnik, 1994). Externally applied peat preparations are used for the treatment of dermatitis, haemorrhage, phlebitis, myorrhexis, muscular induration and contusion, joint luxation, vertebral affliction (cervical and lumbar vertebrae), rheumatoid diseases, ischalgia, arthrosis, arthritis, osteomyelitis etc. (Kotwica et al., 1976a,b; Callies and Kaiser, 1978; Lotosh, 1991; Eichelsdorfer, 1992; Riede et al., 1992; Praetzel, 1993; Banaszkiewicz and Drobnik, 1994; Siderov and Mamiliaeva, 1994; Bellometti et al., 1997; Olivera et al., 1997; Beer et al., 2003a,b).

In farm herds, peat is usually used as bedding. Its structure and soft characteristics exerts beneficial effects on the prophylaxis of animal limb abrasions (Lysons, 1996; Durrling et al., 1998). Due to its absorbent capabilities, peat can reduce the production of odorous emissions in farm environments as well as various environmental pollutants (Abbes et al., 1993; Logan et al., 1997; Jeppsson, 1998; Rizzuti et al., 1999; Hartikainen et al., 2001; Martens et al., 2001; Picot et al., 2001; Choi et al., 2003; Heavey, 2003; Tymczyna et al., 2004).

Recently, the interest of farmers in the use of peat as a feed supplement has increased leading to the emergence of peat preparations onto the market. They are especially recommended for the stimulation of growth and the immune system of piglets and sows (Pavlik et al., 2003). The high content of both beneficial humic substances and other organic and mineral substances, easy application, absence of side effects of humic substances (allergy, resistance) and the absence of residues in products of animal origin (Kuhnert et al., 1989, 1991; Lange et al., 1996a,b) indicate that peat can be used in animal nutrition. Peat does not provide calories, but has various health benefits. One objection to using peat preparations is the lack of reproducibility in results as peat comes from a non-homogeneous bed (Fuchs et al., 1995; Beer et al., 2003b). The purpose of this review was to compare the advantages and risks associated with the use of peat for animal nutrition based on the literature available.

2. Factors determining peat quality

Peat is formed in nature under various biological, chemical, physical and geological conditions that influence its physical-chemical characteristics. When evaluating peat qualities it is important to consider the following: the origin, particularly the age, and botanical composition of plant communities of which the peat was formed; the species and frequency of populations of microorganisms that participate in the process of humification; and the presence of mineral substances in the surrounding peat bed (Enueme et al., 1987; Kazda, 2000; Wise et al., 2000).

2.1. Peat origin

Peatlands are characteristically waterlogged locations usually found on relatively flat landscapes. Cold and anaerobic conditions up to tens of centimetres beneath the surface cause organic residues to accumulate, to depths of at least 30 cm and often up to several metres (Gorham, 1991). A series of complex decomposition and accumulation processes characteristic of this kind of environment lead to the formation of peat. Peat bogs form where the presence of excess of water for most or all the year prevents the complete degradation of organic substances, leading to an accumulation of sediments forming peat (Bozkurt et al., 2001).

The general classification of peatland ecosystems into ombrotrophic bogs, minerotrophic fens and transitional mires is based on the origin of the mire water. In ombrotrophic peatlands the water is supplied exclusively by precipitation, while minerotrophic mires are additionally supplied with water from mineral soil (Andriesse, 1988; Hruska, 1988; Bozkurt et al., 2001).

2.1.1. Ombrotrophic bog

Ombrotrophic (high-moor) bog is formed in beds with poor drainage ability as a consequence of heavy rainfalls, and a lack of minerals, particularly in calcium deficient acidic rocks. High levels of aerial humidity can be observed at higher altitudes so bogs are found mainly in mountains and foothills. Extreme humidity causes delayed decay and accumulation of organic material. Under such conditions, only undemanding vegetation can survive, such as sphagnum moss (*Sphagnum* sp.), haircap moss (*Polytrichum* sp.), cotton grass (*Eriophorum* sp.), dendriform plants, stunted trees [particularly spruce (*Picea* sp.), and pine trees (*Pinus* sp.)]. Growth of higher plants is curbed by the peat mosses themselves as they bind all available nutrients and render the bog water acidic. Oligotrophic peat of high-moor bogs contains very low concentrations of inorganic substances and ashes (2 to 4%); accordingly, it is deficient in mineral nutrients and the level of acidity is high (pH 3 to 4). It is light, crumbly and yellow-brown to brown in colour (Hruska, 1988; Bozkurt et al., 2001; Pereverzev, 2005).

2.1.2. Minerotrophic fen

Minerotrophic (low-moor) fens occur near eutrophic soils or are formed when nutrient rich waters are filled with sediment. The abundance of plant nutrients allows fens to support luxuriant vegetation. Arising in basins rich in minerals (such as limestone clay, marl, pond mud); they contain rather high proportions of inorganic substances, have an elevated ash content (6 to 18%) and a neutral to slightly alkalic pH is (6 to 8). Eutrophic peat of low moors is dark brown to black in colour, heavy, slimy in wet weather, and may be powdered when dried (Hruska, 1988; Bozkurt et al., 2001; Pereverzev, 2005).

In particular higher plants such as sedge (*Carex* sp.), reed (*Phragmites* sp.), cane (*Calamagrostis* sp.), and horsetail (*Equisetum* sp.), birch trees (*Betula* sp.), alder (*Alnus* sp.), pine (*Pinus* sp.), spruce (*Picea* sp.), and some species of moss (*Sphagnum* sp., *Musci* sp. and *Hypnum* sp.) contribute to minerotrophic fen formation (Hruska, 1988; Bozkurt et al., 2001).

2.1.3. Transitional mire

Transitional (mesotrophic) bogs represent a genetic transition between low-moor and high-moor bogs. Ombrotrophic bogs may for example be formed on a minerotrophic fen bed where the peatland is called a raised bog. Transitional mires are only present in moderate to cold climates and are independent of the terrain. They are formed in shallow terrain depressions that are filled with water and gradually overgrown. Composition of this type of peat is varied. Various types of moss (*Polytrichum* sp., *Sphagnum* sp., and *Hylocomium* sp.), dendritic plants, and sedges can be found there. Raised bogs are naturally treeless and convex or domed in form. The ash content is 4 to 6% and there is generally a low reserve of mineral nutrients. The level of acidity is usually moderate to high (Hruska, 1988; Bozkurt et al., 2001; Pereverzev, 2005).

2.1.4. Other peat classifications

Besides the above mentioned topographic classifications, several other classification systems exist that are used for discrimination of different types of peat. Classification is most commonly based on the following (Andriesse, 1988):
i) surface vegetation,
ii) chemical properties,
iii) botanical origin,
iv) physical characteristics,
v) genetic processes.

As the respective classification systems are extensive, detailed description of each peat type will not be presented here.

2.2. Moor structure

Three layers of peatbog structure can be distinguished according to the age and degree of decomposition as well as by colour (Andriesse, 1988; Mitsch and Gosselink, 1993; Kazda, 2000; Wise et al., 2000):
i) fibric peat,
ii) hemic peat,
iii) sapric peat.

Every year, a new green vegetation layer is formed on the surface of a peatbog. It comprises of green sphagnum moss that traps the sunshine and consequently results in heat accumulation in the deeper layers of peat (Kazda, 2000). In this upper aerobic part the degradation is fast, and the easily-utilizable plant constituents such as proteins and simple sugars, are rapidly consumed by microorganisms (Lehtonen and Ketola, 1993). Fibric peat has a fibre content of greater than 67% and more than two thirds of the plant fibres are identifiable (Mitsch and Gosselink, 1993).

Below the surface layer, under anaerobic condition, the degradation rate rapidly decreases due to the lack of oxygen. In the anaerobic layer, oxygen-containing plant constituents form the important oxygen source needed for degradation to proceed. Under anoxic conditions, simple organic molecules such as sugar can degrade and form carbon dioxide and methane. Sulphur containing material can form hydrogen sulphide. These gases are thus important indicators of what degradation processes are active (Bozkurt et al., 2001). In coexistence with the slowly proceeding degradation, the humification process begins (Lehtonen and Ketola, 1993; Kazda, 2000). Hemic peat is intermediate in the degree of decomposition between the less decomposed fibric and more decomposed sapric peat. It has a fibre content and identifiable plant fibre of between 33 to 67% (Mitsch and Gosselink, 1993).

Fully mineralised material is found in the underlying black layer at the depth of about 2 m and contains a high proportion of humic substances and other components that can exert beneficial effects on the organisms (Kazda, 2000). Sapric peat has a fibre content of less than 33% and less than one third of the plant fibres are identifiable (Mitsch and Gosselink, 1993).

In order to define the state of transformation and destruction of the organic matter of peat, a special concept – the degree of decomposition – is used. It reflects the content of amorphous matter consisting of the product of decomposition of the original plants and fine non-cellular fragments of plant tissue. Another concept – the degree of humosity – reflecting the content of humic substances is also employed. No distinction is usually made between these two concepts and the terms are often used interchangeably (Bozkurt et al., 2001).

2.3. Peat composition

The chemistry of peat results from a combination of the chemical compositions of mire plants and microorganisms, the soil water quality and the secondary substances produced during the decomposition process (Bozkurt et al., 2001).

2.3.1. Organic substances

The organic carbon content of peat exceeds 50% of the dry matter (Bozkurt et al., 2001; Pereverzev, 2005). This carbon content in the peat increases with depth. Therefore, the older the peat layer, the more carbonized its organic matter. Different types of peat have nearly the same content of total carbon. By contrast, the concentration of nitrogen varies significantly depending on the proportion of sphagnum in the peat. The C/N ratio changes from 39 in oligotrophic peat to 28 in transitional peat and to 22 in eutrophic peat (Pereverzev, 2005).

The organic matter composition of peat depends on the degree of humification of plant residues. During humification stable humic substances are formed by microbial transformation of non-humic substances (Table 1) such as hemicellulose, cellulose, lignin, pectins, bitumens, waxes, resins, nitrogenous materials, lipids, amino acids, non-saturated and saturated fatty acids, organic sulphur, various types of carbohydrates, starch compounds, ethereal oils, balsam, bioterin and tannic acid (Andriesse, 1988; Hruska, 1988; Riede et al., 1992; Banaszkiewicz and Drobnik, 1994; Anonym, 2002). Humic substances (Table 2) such as humic, fulvic, ulmic acids, and humins are the major part of humified peat (Hruska, 1988; Hruska, 1999; Anonym, 2002; Kocabagli et al., 2002; Janos, 2003; Perminova et al., 2003). They constitute a dark brown non-soluble fraction of peat with an extremely high molecular weight, responsible for the capability to retain water, friability and electrostatic conductivity. Recorded molecular weights

Table 1. Review of non-humic organic substances (according to Andriesse, 1988)

Non-humic substances	Content (%)	Characterization
Water soluble compounds	5–10	The content of water soluble compounds, mainly polysaccharides, monosaccharides, and some tannin is dependant on the stage of decomposition. These substances are the first to leach away on decomposition and the highest contents are therefore found in the least decomposed materials. The original content of water soluble compounds most likely depends on the type of vegetation.
Ether and alcohol soluble materials	5–15	The ether and alcohol extracts, determined separately by some workers, contain fatty acids, wax-like components, resins and nitrogenous fats, some waxes, tannins, various pigments, alkaloids and soluble carbohydrates. The amounts are strongly related to the original vegetation. For example, peat's sphagnum may contain as much as 15% of soluble carbohydrates, reeds and peat's sedge less than 5%. This fraction usually increases with the increasing age of the peat.
Cellulose and hemi-cellulose	5–40	The cellulose and hemi-cellulose fraction decomposes easily so the content in the original vegetation is therefore usually greater than that in the derived peat.
Lignin and lignin-derived substances	20–50	The lignin and lignin-derived materials commonly constitute the largest portion of the peat because they increase in amount on decomposition as other materials are removed. This fraction is estimated by hydrolysis with strong sulphuric acid of the residue after the three fractions above have been removed. Lignin is fairly resistant to microbial attack. The original vegetation also influences the content.
Nitrogenous materials or crude proteins	0.3–4.0	The nitrogenous constituents are small in comparison with the other fractions and mainly proteinaceous in nature. Total nitrogen content may vary on a dry weight basis.

for humic substances range from a few hundred to millions of Daltons. Chromatographic analyses showed that the molecular weight of humic substances is primarily affected by their source (freshwater, soil, peat and coal). The maximum molecular weight and polydispersity values were observed for peat humic and fulvic acid, and soil humic acid (Perminova et al., 2003).

2.3.2. Inorganic substances

Inorganic substances get into peat as earthy mineral ingredients by water or wind or as mineral substances, originally bound in plant organisms. Their content in peat is not usually higher than 10% (Hruska, 1988). There is generally a wide variation in mineral composition between different peats but apart from carbon, hydrogen, nitrogen and oxygen the principal constituents are either calcium or silicon (Sanovec, 1947; Andriesse, 1988; Anonym, 2002).

In contrast to mineral soils with a predominance of silicon in their bulk elemental composition, the ash of peat is characterized by a predominance of calcium. The proportion of calcium and silicon characterizes the genetic features of peat. The ratios of Ca/Si in high-moor, transitional, and low-moor peat constitutes 3.7, 2.5, and 1.8, respectively. This ratio can serve as a diagnostic index of the trophic state of the peat (Pereverzev, 2005). The silicon usually comes from wind-blown minerals or washed-in sediments and so only constitutes a small proportion (Andriesse, 1988).

The contents of iron, aluminium, sodium, sulphur and phosphorus reaches high levels in some peat. This is usually caused by particular environmental conditions which operated during the paludification period. As a result of environmental changes the various layers of peat deposits often show differences in elemental composition. Microelements present in peat are B, Sr, Zr, Cr, Ag, Au, Ba, Ti, V, Cu, Mn, I, and Co (Sanovec, 1947; Andriesse, 1988; Anonym, 2002).

Table 2. Review of humic organic substances

Humic substance	Description of humic substances	References
Humic substances	Stable humic substances also called humates. Constitute 60 to 80% of peat.	Hruska (1988), Hruska (1999), Anonym (2002)
Humic acids	A series of similar, aromatic polyfunctional compounds with medium to high molecular weight, dark brown in colour, and soluble in alkalic solvents. According to the degree of decomposition, peat types comprise of different proportions of humic acids, in some cases up to 50% or more. Humic acids have cation and anion exchange sites.	Hruska (1988), Visser (1973, 1988) Anonym (2002), Janos (2003)
Fulvic acids	Substances with a similar composition, but lower molecular weight are designated as fulvic acids. They are yellow in colour and are soluble in both alkalic and acidic environments. Humic and fulvic acids are sometimes designated collectively as humic acids. In the peat of low-moor and transitional bogs, there is a more significant predominance of humic over fulvic acids than in the peat of high-moor bogs.	Anonym (2002), Janos (2003), Pereverzev (2005)
Ulmic acids	Part of the peat that is dark in colour, soluble in alcohol and not well-recognized is designated as ulmic acids.	Anonym (2002), Janos (2003)
Humates	Humates are the salts of humic acid in which the exchange site is the cation of Ca, Na, Al, and Fe rather than hydrogen.	Kocabagli et al. (2002)
Humins	Humins are not extracted by NaOH solution but can readily be digested with cold 72% H_2SO_4.	Andriesse (1988), Anonym (2002), Janos (2003)

2.3.3. Other biologically active substances and microorganisms

Microorganisms play a dominant role in the decomposition and mineralization of organic matter in peat. Most of these belong to the bacteria, actinomycetes and fungi (Andriesse, 1988). Sphagnum peat contains species *Bacillus, Arthrobacter, Actinomyces, Streptomyces, Penicillium, Cladosporum, Trichoderma, Mucor* etc. (Tahvonen, 1993). Among the biologically active substances with antibiotic characteristics present in peat are streptomycin and penicillin; also found are estrogenic substances, vitamins, hormones, and enzymes. The majority of healing effects of peat can be explained by the presence of biologically active non-saturated fatty acids, essential for organisms (Anonym, 2002).

3. Effects of peat on organisms

The effects of peat and various peat extracts are dependent on the possible permeability of biologically active substances as naturally occurring ingredients of peat (Beer et al., 2003b). Although most beneficial effects are associated with the presence of humic acids, biological activity of natural peat is viewed as being more beneficial compared to isolated humic acids (Banaszkiewicz and Drobnik, 1994).

3.1. Stimulation of digestion

3.1.1. Reduction of pH in the intestine

Peat preparations provide protection for the highly sensitive mucosa of the digestive tract, stomach and intestines, particularly in young farm animals. Accordingly, peat is commonly used as a feed supplement for piglets to prevent diarrhoeal diseases. Due to its low pH (3.0 to 5.5) peat causes a reduction in the pH of the intestinal contents with consequent control of intestinal microflora (Shermer et al., 1998) and limited growth of the animal pathogenic bacteria of family Enterobacteriaceae. Experiments in two-day old calves preventively fed peat in doses of 200 g/day dispersed in milk for 16 days and in doses of 400 g/day in cases of calves with diarrhoea showed beneficial effects of decreased duration of diarrhoea and reduced mortality (Lenk and Benda, 1989). Kuhnert et al. (1989, 1991) used humic acid to treat digestive disorders and diarrhoea in cats and dogs.

3.1.2. Effect on the contraction activity of smooth muscles

Peat contains a large number of water-soluble components, which have stimulatory effects on the spontaneous contractile activity of smooth muscle tissue (Beer and Lukanov, 1998; Beer et al., 2000; Zagorchev et al., 2000; Beer et al., 2003b). These are chemically stable substances that are unchanged in aqueous solution and retain their biological activity for months (Beer et al., 2002). It was found that the excitatory effect occurred through activation of the α2-adreno- and D2-dopamine receptors. The arrest of these effects after prolonged impact is due to the inactivation of the same receptors (Beer et al., 2000, 2002). The excitatory effect of water peat extracts on the spontaneous contractile activity of smooth muscles is due to the organic compounds with molecular weight under 3 kDa (Zagorchev et al., 2000). As humic acids present in peat cover the open nerve endings in mucosa, there is a reduction in the excitability and potentially stressful conditions of animals with lesions of intestinal mucosa (Slavik, 1999).

3.1.3. Improvement of nutrient uptake and conversion efficiency

Fulvic acids present in peat can form chelate complexes with mineral elements and change their electric charge, allowing fast uptake by the organism. Humic acids induce an increase in permeability of cell membranes and thus facilitate transport of minerals from blood into cells (Visser, 1973; Anonym, 2002). Elements such as Mn, Fe, and Zn are known to be able to participate actively in ligand formation with many organic compounds, and therefore it may be that humic acids, which are known to be excellent ligand formers, can facilitate transport through biological membranes in a similar way (Visser, 1973).

The capability of humic acids to form chelate complexes with trace elements and facilitate uptake of nutrients by the plant cells is used for growing plants. The application of humates in animal nutrition has a very short history (Kocabagli et al., 2002).

Fuchs et al. (1990) investigated the bioavailability of iron bound as a chelate to macromolecular humic acids. Twenty-one days after a single oral application of the humic-acid-iron complexes, 25% of the total Fe was detected in the animal, distributed in the erythrocytes (80%), muscles and bones (8%), and liver (4%). For the first time in veterinary medicine a combined therapy for enteric and iron-deficiency syndrome was able to be treated using only one drug.

3.1.4. Detoxifying capability of peat

Humic and fulvic acids can also form chelate complexes with a number of toxic substances (heavy metals such as lead, mercury, cadmium, chromium, toxins produced by pathogenic bacteria, moulds, pesticides etc.). However, unlike chelate complexes with mineral substances, they have a neutral charge, are insoluble and their uptake by organisms is difficult (Klocking, 1980; Kuhnert et al., 1982). Accordingly, they are excreted through the intestine and are neither deposited in the organism nor do they exert adverse effects on the organism (Kuhnert et al., 1982). The effect of humic acids on heavy metal ion toxicity to experimental animals was found to be dependant on the technique of application and the applied dose (Klocking, 1980; Visser, 1988; Stackhouse and Benson, 1989; Herzig et al., 1994). Whereas higher doses of humic acids (50 mg/l) led to a decreased toxicity of chromium in fish, no decrease was observed with lower doses (0.5 to 5 mg/l) (Stackhouse and Benson, 1989).

3.1.5. Effect on biochemical and haematological characteristics

Certain studies focus on beneficial effects of peat preparations on lipid metabolism (Stepchenko et al., 1991; Banaszkiewicz and Drobnik, 1994; Bailey et al., 1996) and their potential use for treatment of lipid metabolism disturbances (hypercholesterolemia) (Banaszkiewicz and Drobnik, 1994). After feeding peat to rats, the levels of total cholesterol, total lipids and glucose decreased, and levels of high density lipoprotein (HDL), globulin, haemoglobin, hematocrit and counts of erythrocytes increased (Banaszkiewicz and Drobnik, 1994). Supplementation of turkey feed ration with 1.0% humate resulted in a significant decrease in the thickness of the abdominal fat layer, although lower humate concentration (0.5%) in the ration did not show that effect (Bailey et al., 1996). Likewise in broilers fed with 0.25% humate in the feed ration, no significant abdominal fat decrease was observed (Kocabagli et al., 2002).

Besides the improvement of lipid metabolism, peat preparations also bring about improvement in the metabolism of proteins, minerals and enhanced organism protection and adaptation opportunities in animals (Stepchenko et al., 1991). The amount of total protein in blood sera of chicken broilers fed sodium humate increased at the end of the fattening period by 8 to 10% and in leg and breast muscles by 6 and 10%, respectively. The profile of protein fractions in blood sera changed: albumins and total immunoglobulins increased and globulins decreased. The ratio of saturated and non-saturated fatty acids in liver and breast muscles was positively affected. Total lipid content in liver decreased and in breast and leg muscles increased non-significantly. After humate feeding, increased levels of some essential minerals (Ca, Al and Fe) in blood sera, liver and muscles were recorded (Stepchenko et al., 1991).

3.2. Stimulation of growth and production performance in animals

In the past, various studies referred to the beneficial effect of peat preparations on growth, carcass dressing percentage (Roost et al., 1990; Stepchenko et al., 1991; Zhorina and Stepchenko, 1991; Fuchs et al., 1995) and reduction in the occurrence of unspecific deaths of animals (Lenk and Benda, 1989; Stepchenko et al., 1991).

Stimulation of growth and production performance has been observed for instance after application of humates to feeds or drinking water for poultry (Stepchenko et al., 1991; Bailey et al., 1996; Shermer et al., 1998; Kocabagli et al., 2002; Yoruk et al., 2004).

Stepchenko et al. (1991) show that after the feeding diets containing 0.25% peat preparation from the age of 22 days, broiler chickens gained weight by 5 to 7% (Table 3), and the mortality rate was reduced by 3 to 5%.

The feeding of humate during the growing period has the most beneficial effect in terms of growth and feed conversion on broiler performance. Body weights, feed consumption and feed conversion efficiency at 21 day were not affected by the dietary regimens. At day 42, body weights and feed conversion of broilers were significantly affected by the dietary humate treatments (Table 3). The highest body weight was recorded in group fed diets supplemented with humates from the age of 22 days. Neither total feed consumption nor mortality rate were statistically significantly affected by humate supplementation (Kocabagli et al., 2002).

Although there is not enough evidence to hypothesize how humates promote the growth in broilers, it is assumed that humates might increase the uptake of nitrogen, phosphorus, and other nutrients due to their chelating properties. This assumption needs to be further validated in poultry (Kocabagli et al., 2002).

Shermer et al. (1998) examined the short-chain fatty acids, amino acid concentrations, and microbial populations in the digestive track of birds fed diets containing 0.5 or 1.0% of humate. They hypothesized that humates might influence the performance of birds by altering the microflora in the gastrointestinal system, e.g., in the cecum, however, they found that feeding humates at various levels did not influence the cecal concentrations of the short-chain fatty acids. Only *Escherichia coli* populations were increased by the increased levels of dietary humate (Shermer et al., 1998).

Supplementation of feed ration for layers with 0.1 to 0.2% humates resulted in increased egg production, enhanced feed conversion efficiency and led to reduced mortality rates of the hens. Neither feed consumption nor quality of eggs was affected by humate supplementation of feed ration (Yoruk et al., 2004).

Peat preparation fed as a supplement to piglets exerted a beneficial effect on their growth and general health status. Piglets fed with mixtures containing peat preparations also showed a lower mortality rate (Roost et al., 1990; Fuchs et al., 1995). A higher intake of feed rations containing peat (0.30 kg/day/piglet) was recorded in comparison with control feed rations without peat supplementation (0.19 kg/day/piglet). Although no significant differences in the body weight of experimental and control piglets were observed before day 28, the average body weight of piglets fed with peat was higher on day 59. The same dependences were found with respect to the daily body weight gain of the piglets from day 29 to 59 of life (Table 3). All groups of piglets that received peat preparation or antibiotics showed better growth from day 59 of life compared to the negative control (Fuchs et al., 1995).

There is industrial interest in using peat as a dietary carrier for liquid by-products, feed products and feeding mixtures (e.g. molasses, lignin sulphonate, streptomyces solubles, fish solubles, vitamines) (Enueme et al., 1990). Peat is viewed as cheaper and more hydrophilic in comparison with other often used carrier-type feed ingredients such as rice hulls, sunflower hulls, peanut hulls, soybean mill feed, wood flour, and corn cobs. It is

Table 3. Effect of dietary peat preparation on live performance of animals

Animal species	Group	Peat preparation	Dietary peat level (g/kg)	Period of feeding peat (age in days)	Body weight (kg)	Daily gain (g)		Feed:gain (g/g)		References
Broilers	Negative control	–	–	–	1.34^{a}	26.7		–		Stepchenko et al. (1991)
	Experimental	Natrium humate	0.25	20–56	1.44^{b}	29.4		–		
					(day 42)			(22–42 d)	(0–42 d)	
Broilers	Negative control	–	–	–	2.35^{a}	–		2.14^{a}	1.99	Kocabagli et al. (2002)
	Experimental	Humate	2.5	0–21	2.39^{ab}	–		2.03^{ab}	1.95	
				22–42	2.45^{b}	–		1.99^{b}	1.89	
				0–42	2.43^{ab}	–		1.99^{b}	1.92	
					(day 100)	(29–59 d)	(60–100 d)	(prestarter)	(starter)	
Piglets	Negative control	–	–	–	33.70^{a}	259^{a}	467	3.07^{a}	3.11	Fuchs et al. (1995)
	Antibiotic control	–	–	–	36.74^{b}	310^{b}	489	2.54^{b}	2.85	
	Experimental	Tolpa 1*	0.3	6–100	34.31^{a}	306^{b}	435	2.59^{b}	2.96	
		Tolpa 2*			35.95^{b}	318^{b}	463	2.63^{b}	2.80	
		Tolpa 3*			36.66^{b}	297^{b}	498	2.38^{b}	2.81	
Turkeys	Negative control	–	–	–	12.75	–		2.97^{a}		Enueme et al. (1987)
	Experimental	Hemic peat	50	0–140	12.58	–		3.09^{b}		
			100		12.43	–		3.36^{b}		
	Negative control	–	–	–	0.50^{a}	–		1.50^{a}		
	Experimental	Hemic peat	50	0–21	0.49	–		1.60		
			150		0.44^{b}	–		1.70^{b}		
Lambs	Negative control	–	–	–	48.9	23.3^{a}		4.67^{a}		Enueme et al. (1990)
	Experimental	Hemic peat	100	0–63	46.2	20.8^{b}		6.16^{b}		
			200		41.8	15.8^{b}		8.46^{b}		
			300		35.8	10.3^{b}		9.81^{b}		

$^{a}P < 0.01$; $^{b}P < 0.05$

*waste product left during the process of production of Tolpa peat preparation for human medicine highly absorbent and therefore may rapidly reduce moisture levels, minimizing litter build up as less frequent addition is necessary. Enueme et al. (1987) recommend using peat as a carrier-type feed for turkey feed rations in the dose of 2 to 4%, to prevent growth depression in the animals that had been observed with higher concentrations (15%) of peat or other commonly used carriers.

Growth depression was also observed when peat was included in the diets, replacing a similar amount of alfalfa (Table 3). This method of substitution may have been stressful in that the nutrients in the alfalfa were replaced by an ingredient of low available nutritional content thereby disturbing the original nutritional balance. The amount of feed required per gain increased considerably with increasing peat in the diet. Analysis of the body gain depression due to peat by linear regression showed that the depression disappeared at 23 g peat/kg diet. The results suggest that peat would be a safe dietary carrier at 20 to 30 g/kg diet. Although gains were depressed at higher levels, in all instances these animals showed a healthy appearance, absence of gross abnormalities upon necropsy, and acceptable carcass sensory characteristics (Enueme et al., 1990).

The effect of peat on growth stimulation has not yet been thoroughly studied in animal production in the Czech Republic. The effect of a preparation containing humic acid WH 67 and various types of minerals as the main constituent has only been tested (Slavik, 1999). Results showed that preparation with recommended proportion 0.5 to 1.0% of the feed ration, usually 0.6%, increases live body weight and promotes the feed conversion efficiency. Humic acids can cause a reduction in feed consumption by piglets by 1.3 to 5.3% with concurrent increase in the body weight gains by 2.2 to 9.4% (Slavik, 1999). It follows from the experience of some large scale farms that the use of peat is also economically highly profitable (Pavlik et al., 2003*).* Peat preparation used as a growth stimulator should be standardized and its activity should be known (Fuchs et al., 1995).

3.3. Effect of humic substances on health

The feeding of peat preparations can affect the composition of intestinal microflora. Some strains of eubacteria and actinomycetes isolated from the soil are able to produce antibiotics (Huck et al., 1991). Moreover, Shermer et al. (1998) described that the intestine of chickens fed mined humate compound in the diet contained 10 to 100 times more *Escherichia coli* than in the control birds.

Peat preparations are beneficial in protection from viral diseases. The mechanism of antiviral effect of humates present in peat likely consists in the fact that they bind viral particles preventing them from adhering to the cell surface. In veterinary medicine, peat humic acids have proven to be beneficial in prevention of the foot-and-mouth disease spread among pigs (Schultz, 1965). Beneficial effects of humates against rhinovirus infections (Sydow et al., 1986), coxsackie A9 virus (Klocking and Sprossig, 1972), herpesvirus type 1 and 2 (Thiel et al., 1977, 1981; Schiller et al., 1979), human immunodeficiency virus *HIV/AIDS* (Schols et al., 1991; Laub, 2000), virus of influenza type A and B (Mentel et al., 1983; Sydow et al., 1986; Schols et al., 1991; Laub, 2000), and also in other infections of the respiratory tract (Schultz, 1965; Klocking and Sprossig, 1972; Sydow et al., 1986; Jankowski et al., 1993) have been observed.

Humic substances present in peat can increase the activity of the immune system. The mechanism of action of humic substances is associated with their capability to form complex saccharides in the body that act as modulators of intercellular interactions. They keep the activity of the immune system in balance and prevent potential inadequate responses that may produce a series of illnesses such as autoimmune diseases. This finding by Riede et al. (1991) is essential. These authors refer to the fact that humic substances under *in vitro* conditions can activate granulocytes leading to the production of toxic oxygen intermediates, mainly H_2O_2. Other parameters, such as neutrophilic chemokinesis or chemotaxis were not affected.

Beneficial therapeutic effects of locally or generally applied humic substances with the purpose to reduce undesirable infections in the patients suffering from burns or irradiation diseases have been proven. For example, the survival of rats after exposure to lethal doses of cobalt irradiation can be prolonged by application of sodium humates (Pukhova et al., 1987). Humic substances from peat show marked anti-inflammatory properties (Kuhnert et al., 1982). Therapeutic effects in recurrent respiratory tract infections were seen after oral administration of a peat preparation. Likewise cervicitis can be treated with preparations made of these substances (Jankowski et al., 1993). Humic substances attenuate swelling concurrent to joint inflammations. Moreover, they can bind to collagen fibres and help healing of damaged tendons and bones (Riede et al., 1992).

4. Risks associated with peat as a feed supplement

4.1. Risks of feeding humic substances as a supplement

The risk of feeding animals with peat as a supplement has only been thoroughly studied from the aspect of the effect of humic substances. Humic substances are natural constituents of the food chain, present in all plant and animal organisms. Experiments in rats, mice, calves, and piglets showed that the toxicity of humic substances is extremely low (Thiel et al., 1981; Riede et al., 1992; Faqi et al., 1996; Lange, 1996a,b). On the basis of gross and histochemical examinations, various studies confirmed safety of humic acids in relation to blood, cardiovascular and endocrine systems and also to other vital organs. They do not produce allergic responses or interfere with other medications and are not embryotoxic (Thiel et al., 1981; Faqi et al., 1996; Lange, 1996a,b). The presence of residues of humic substance in animal tissues can be ruled out with high significance (Lange et al., 1996b).

Humic substances are generally viewed as environmental goitrogens. In endemic areas with high concentrations of humic substances in water, increased incidence of goitre was observed (Huang et al., 1994). However, studies investigating the effects of humic acids on rat and mouse thyroid gland function did not detect adverse effect of these substances in animals given either normal or iodine deficient diets. Thus, humic acids do not induce goitre, but may enhance the goitrogenic effect of low iodine (Huang et al., 1994).

However, it is not clear from the literature available whether any other substances present in peat can exert adverse effects to a living organism as information about the adverse effects of peat is very limited. Some risk factors from the aspect of infection of diseases by pathogens have however been recognized (Horvathova et al., 1997; Matlova et al., 2005).

4.2. Mycobacterial contamination of peat

The potential health risk of feeding peat as a supplement particularly exists in the occurrence of so called "atypical or potentially pathogenic mycobacteria" in the external environment that can contaminate sterile underground peat after extraction (Horvathova et al., 1997). The finding of high concentrations of mycobacteria, particularly in hemic (middle) layer of peat, is due to the favourable conditions for their growth and development, which may be unfavourable for other bacterial species (Kazda, 2000).

4.2.1. Fibric peat contamination

Conditions in the surface green layer of peat are unfavourable for the propagation of mycobacteria resulting in zero occurrences (Kazda, 2000). An important characteristic of this layer is its very low pH level (2.0 to 2.5) that prevents colonization by other species of plants and microorganisms with the exception of sphagnum (Horvathova et al., 1997; Kazda, 2000). Other important factors restricting the survival of microorganisms are extreme changes in temperature and the desiccation of this layer.

4.2.2. Hemic peat contamination

Substances present in the grey layer of peatbog represent a source of carbon and nitrogen necessary for the growth and development of mycobacteria. Other important factors enabling their growth are an optimal pH value (4.5 to 5.0) and temperature, which can be 15 to 20°C higher than on the peatbog surface. The highest concentration of mycobacteria is found in the grey layer and reaches from 1 to 10 million CFU/g of peat matter. Mycobacteria can contaminate sapric peat situated below hemic peat after mining (Horvathova et al., 1997; Kazda, 2000).

4.2.3. Sapric peat contamination

The deep, so called black layer, contains less mycobacteria due to unfavourable conditions for growth; the deeper the layer, the less mycobacteria are present (Horvathova et al., 1997). In study carried out by Kazda et al. (1989) peat from the depth of more than 2 m is considered as sterile, although additional contamination with rainwater, dust or soil was recorded (Kazda, 2000).

4.3 Occurrence of mycobacterial species in peat bogs

Despite the fact that peat bogs are generally low in nutrients and living organisms, they provide appropriate conditions for survival and propagation of a wide spectrum of mycobacterial species. Mycobacteria have been detected so far in all of the investigated peat bogs worldwide; 41.2% of collected samples were positive (Horvathova et al., 1997). A total of 26 mycobacterial species have been isolated (Muller and Kazda, 1987); the most common are: *M. fortuitum*, *M. flavescens*, *M. chelonae*, *M. gordonae*, *M. thermoresistible*, *M. xenopi*, *M. vaccae*, *M. szulgai*, *M. smegmatis*, *M. diernhoferi*, *M. avium*, *M. scrofulaceum*, *M. gastri*, *M. aurum*, and *M. simiae*. Some of these species are most important from a clinical aspect (particularly *M. avium*, *M. xenopi*, and *M. simiae*). The following five recently described mycobacterial species are also limited to peat bogs: *M. sphagni*, *M. komossense*, *M. cookii*, *M. madagascariense*, and *M. hiberniae* (Kazda, 2000).

4.4. Additional mycobacterial contamination during storage of peat

After mining, peat (mainly from the black layer) is stored in stockpiles before further processing. Stockpiles are placed in open spaces, unprotected from the influences of the surrounding environment. During storage additional contamination of peat from various sources may occur. The most important of these are rainwater and surface water that contain high concentrations of mycobacteria (Beerwerth, 1973; Kazda, 1973). Other sources of atypical mycobacteria such as dust, soil, bird faeces etc. should also be considered (Beerwerth and Schurmann, 1969; Dawson, 1971; Beerwerth and Kessel, 1976a,b). Contamination with mycobacteria of *M. avium* complex and other mycobacterial species such as *M. fortuitum*, *M. chelonae*, and *M. xenopi* are particularly important.

It is not possible to prevent contamination under field conditions. Sometimes peat is stored in unfavourable conditions for a long time during the summer months. Temperatures higher than 18°C are optimal for mycobacterial growth and proliferation, so a relatively small amount of mycobacteria can rapidly propagate to high concentrations (Kazda, 2000).

After processing, peat is distributed in different forms, used in gardening and households for plant cultivations or as a feeding supplement for piglets. In both forms of processed peat, a high concentration of mycobacteria was found (Matlova et al., 2003, 2005). Use of peat contaminated with mycobacteria can influence the health of both humans and animals. To prevent health problems, decreasing the amounts or devitalisation of mycobacteria in peat is necessary (Matlova et al., 2005).

4.5. Occurrence of mycobacteria in peat in the Czech Republic

In the west parts of the Czech Republic, like the rest of the world, mycobacteria were isolated from peatbogs (Kazda, 2000). Mycobacteria were detected in natural peatbogs (surface mines) in Southern Bohemia in peat used as a feed supplement for piglets and in horticultural peat from an unknown origin from a supplier chain (Matlova et al., 2003; Pavlik et al., 2003).

Between 1990 and 1997 the prevalence of tuberculous lesions in lymph nodes of slaughtered pigs in Czech Republic had a slight decreasing tendency (from 0.45% to 0.19%). However, in 1998 and 1999 when peat started to be used on some pig farms as a feed supplement the occurrence of tuberculous lesions in pig lymph nodes increased up to 0.30% (Pavlik et al., 2003).

From the beginning of 1998 piglets were fed peat as a supplement: commercial, calibrated peat either enriched with trace elements, or natural peat after extraction from mines, or horticultural peat for gardeners´ supply. During 1996 to 2002 different materials of stable environment from pig farms were tested to presence of mycobacteria. The most contaminated material was found to be peat (65.1%). *M. avium* subsp. *hominissius* comprised 81.2% of all isolated mycobacteria from peat. Other isolated mycobacteria were *M. a. avium*, *M. fortuitum*, *M. gordonae*, *M. terrae*, *chelonae*, *M. flavescens*, and *M. xenopi* (Matlova et al., 2003).

Peat as a feed supplement and bedding should be viewed as a highly risky raw material from the aspect of its contamination with mycobacteria and resultant finding of tuberculous lesions in pigs. In one studied pig farm occurrence of tuberculous lesions was found in 69.2% of slaughtered pig. The composition of isolated mycobacterial species from pig was similar as isolates from peat (Matlova et al., 2005; Pavlik et al., 2005a,b).

5. Conclusions

The use of peat in feed rations is not based on providing energy, but on its health benefits. The literature refers to a wide spectrum of beneficial effects of peat and various peat preparations on organisms. Stimulating effects on digestion, growth, and the immune system of the animals and absorbent and detoxifying capability are the most discussed. These beneficial effects are most likely to be associated with a high content of humic acids and other organic and inorganic substances. The marked heterogeneity of different types of peat is caused by different biological, chemical, physical, and geological conditions during peat formation. Biological activity of various peat preparations is not only conditioned by chemical composition and physical-chemical qualities of peat, but also by the techniques of application. Based on the existing studies, it is not clear what technique of application is most effective for respective animal species. Further studies should be conducted to elucidate the problem, and farm animals should be included. Potential risk of peat feeding is represented by its primary or secondary contamination with mycobacteria. Provided feed rations are supplemented with peat preparations, it is necessary to minimize potential contamination of the peat during mining, processing and storage.

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